A COOPERATIVE ASSISTANCE SYSTEM BETWEEN VEHICLES FOR ELDERLY DRIVERS

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This paper proposes a new concept of elderly driver assistance systems, which performs the assistance by cooperative driving between two vehicles, and describes some experiments with elderly drivers. The assistance consists of one vehicle driven by an elderly driver called a guest vehicle and the other driven by a assisting driver called a host vehicle, and the host vehicle assists or escorts the guest vehicle through the inter-vehicle communications. The functions of the systems installed on a single-seat electric vehicle are highly evaluated by subjects of elderly drivers in virtual streets on a test track.

Key Words: Driving assistance system, Inter-vehicle communication, Elderly driver, Intelligent Transport System

1. INTRODUCTION

The rapid increase in the elderly population has caused serial issues in Japan. Especially, elderly people (over 65 years old) account for more road fatalities than any other age group (Fig.1). Figure 2 shows the changes in the number of drivers who have a drivers' license. This figure shows the number of elderly drivers is increasing and surpassed that of young divers[1]. One of the issues is automobile traffic accidents caused by elderly drivers. The number of fatal accidents, the main cause of which is due to the elderly drivers, has increased nearly three times in the past 17 years, while the total number of fatal accidents has decreased by nearly 30 % during the same period[1]. Automobiles are the optimal transportation means for the elderly, because they can provide door-to-door transportation. It is the reason why the elderly driver assistance will be necessary.

An ordinary driver assistance system usually involves a single vehicle, and sometimes there are bounds on the assistance. An example that shows the existence of the bounds is assistance at a blind intersection. Another example is the assistance on lane changing, and the system can tell the timing of the lane changing, but if the driver is hesitating and cannot make the decision to perform a lane change, the driver will have to wait for a gap

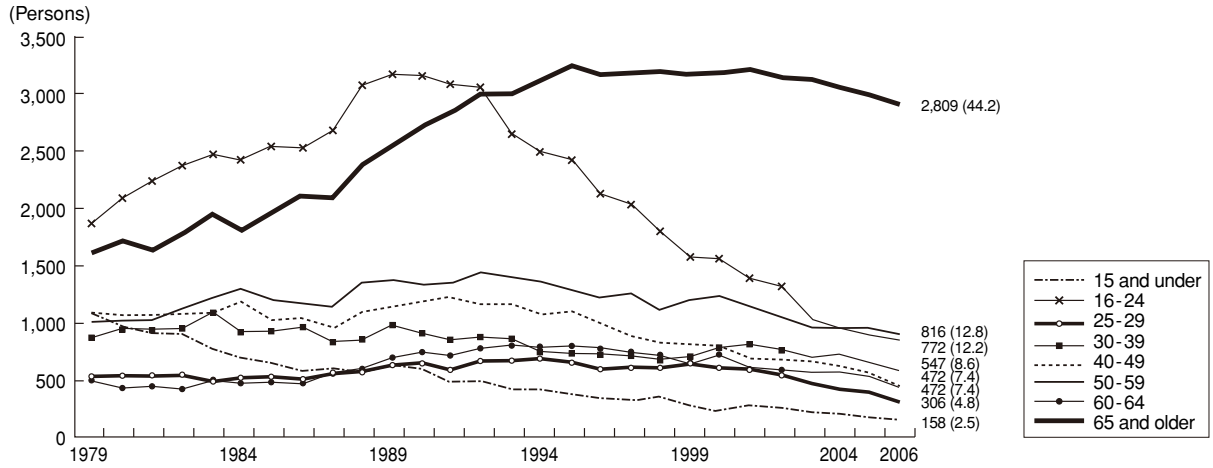


Fig.1 Changes in traffic accident fatalities, by age group

large enough to make a lane change.

The driver assistance proposed here is a new driver assistance that does not have such bounds found in a driver assistance involving only a single vehicle, but it is based on cooperation between two vehicles, named cooperative driver assistance[2]. In the assistance system, the vehicle that is assisted is called a guest vehicle, and the vehicle that assists is called a host vehicle or an escort vehicle. The host vehicle, usually driven by an experienced driver, will assist or escort the guest vehicle, usually driven by an elderly driver. The cooperative driver assistance described in this paper is for a small, single-seat electric vehicle designed for the elderly, as shown in Figure 3.

Much work has been done in the area of the cooperative intelligent vehicles like the papers in the transactions[3]. This paper also focuses on cooperative vehicles based on inter-vehicle communications, but the vehicles are substantially driven by a human driver rather than automated vehicles. The intelligent system of the vehicle is not for automated driving, but for driver assistance. In this paper, novel elderly driver assistance will be proposed taking account of their characteristics, and some experiments and evaluation with newly developed single seat electric vehicles along a virtual urban street on a test track with the subjects of elderly drivers will be reported.

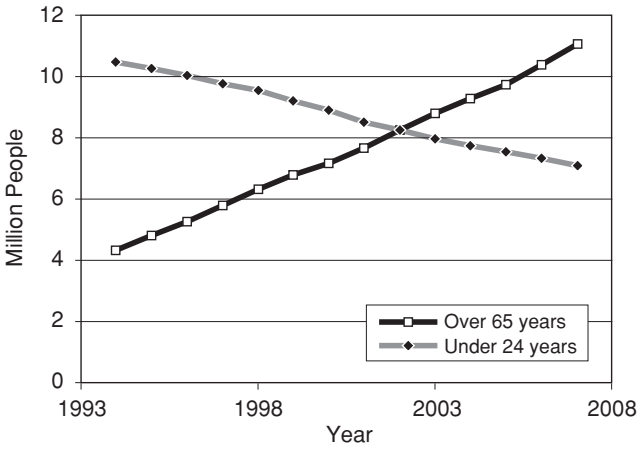


Fig. 2 Changes in number of drivers who have driver license (young and elderly)

Fig. 3 The newly developed single seat electric vehicle

2. THE CHARACTERISTICS OF ELDERLY DRIVERS

With the background of the aging society in Japan, there are many studies focusing on the behaviors of elderly people, and the characteristics of elderly drivers are summarized as follows[4,5]:

(1) They often drive so slowly that they cannot follow the through traffic flow;
(2) They often neglect stop signs, and it is one of the major causes of fatal accidents by elderly drivers;
(3) They often make shortcuts on right turns, and detour on left turns (in Japan the traffic rules are "keep left");
(4) They often make abrupt steering operation;
(5) The longitudinal operation of a vehicle by elderly drivers becomes unstable, when the driving workload increases;
(6) They often neither care about nor watch their surroundings;
(7) They often neglect guidance sign boards;
(8) The level of the surroundings watching for safety by elderly drivers is low. In particular, the surrounding watching for safety at intersections is insufficient;
(9) The elderly drivers ability of the perception of predictable danger and potential danger is low;
(10) The self-evaluation of the driving capability by elderly drivers is high, but the evaluation by instructors in driving schools is low, which indicates the over-confidence on the driving capability of elderly drivers.

The characteristics indicate that ordinary driver assistance that uses equipment on a single vehicle will be sufficient but driver assistance based on a new concept will be necessary.

3. THE CONCEPT OF THE ASSISTANCE

The characteristics of the elderly drivers described above indicate that driver assistance on a single-seat vehicle for an elderly driver must not only be on the single vehicle itself, but also must be from another vehicle or the

host vehicle. The cooperative driver assistance will be effective especially for elderly drivers, whose driving performance is decreasing. The concept of the system is shown in Figure 4, and the system configuration is in Figure 5.

As illustrated in Figure 2, the fundamental concept of the new assistance is that a vehicle driven by an elderly driver is assisted by another vehicle driven by an experienced driver. We call such assistance "cooperative driver assistance."

The assistance can be categorized into two cases: in one case, the host vehicle accompanies the guest vehicle for a while, and in the other case, the host vehicle temporarily assists the guest vehicle.

When the host vehicle accompanies the guest vehicle for a while, the host vehicle drives ahead of the guest vehicle, or side by side with it, or after it, depending on the necessity of assistance by taking care of or escorting the guest vehicle for the safe driving[2]. The forms of the assistance include the following cases: when the guest vehicle approaches a stop sign, the host vehicle goes ahead of the guest vehicle to make the guest vehicle stop at the sign, and when the guest vehicle intends to make a lane change, the host vehicle drives after the guest vehicle and makes the lane change before the guest vehicle to ease the lane changing by the guest vehicle. At a specific, small area like a parking lot, roadside equipment, fixed or mobile, can be employed like an assisting vehicle.

When a vehicle driven by an elderly driver encounters another vehicle at an intersection, for example, the vehicle driven by an elderly driver will be temporarily assisted by the other vehicle by providing the elderly driver with enough time for maneuvering with the use of the communications. This paper focuses on this case of assistance. In the temporary case of the assistance, if the locations of approaching vehicles at intersections are transmitted over the inter-vehicle communications, it works to warn drivers of other vehicles to prevent collisions. Figure 6 illustrates the way of the assistance. Figure 7 shows

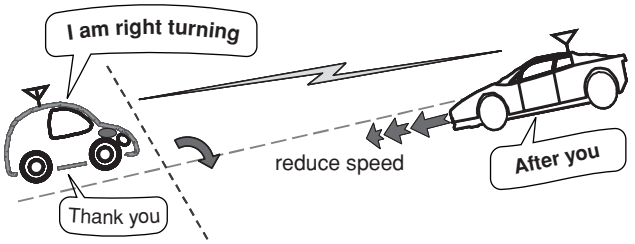


Fig. 6 The way of the assistance

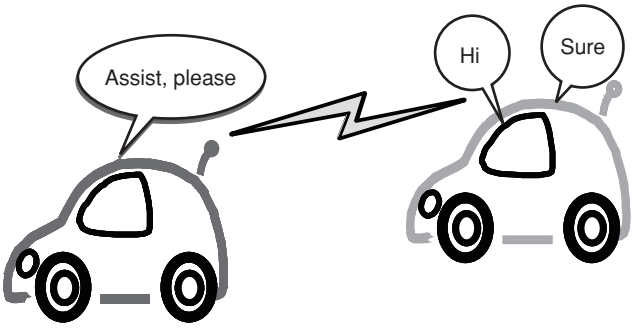


Fig. 4 The concept of the assistance system

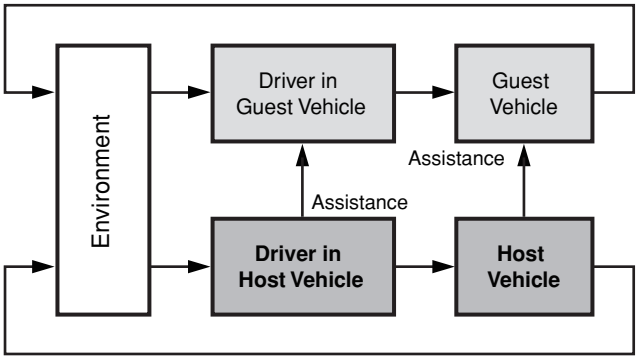


Fig. 5 The configuration of the assistance system

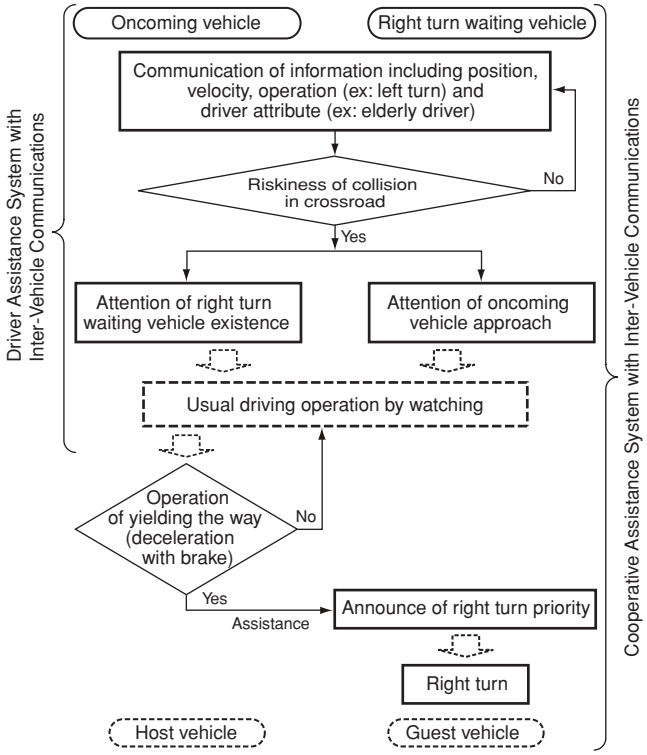


Fig. 7 An example of process flow in intersection shown in Figure 6

the example of process flow in the situation expressed in Figure 6. The feature of this proposal is that the host vehicle assists the guest vehicle, compared with other assistance systems with inter vehicle communication.

4. THE COOPERATIVE DRIVER ASSISTANCE

4.1 The function

The host vehicle and guest vehicle are provided with the cooperative driver assistance system in addition to the ordinary, stand-alone driver assistance system for each vehicle itself. The key technology for the cooperative driver assistance system is the inter-vehicle communications[6,7]. Because the cooperative driver assistance must exchange driving data including the localization and the velocity between the vehicles in order to assist and to be assisted, the inter-vehicle communications are essential. In addition, the localization function, and a driving instruction function will be necessary.

4.2 Experimental systems

We have developed a couple of cooperative driver assistance systems: a cooperative driver assistance system at an intersection from a oncoming vehicle, which will be described here in detail, automated parking that employs roadside equipment, mobile or fixed, to guide a vehicle to a parking space[8], and a two vehicle platoon, where the lead vehicle is driven by an experienced driver and the trailing vehicle in which an elderly driver is automated follows.

5. EXPERIMENTS AND EVALUATION

The experiments on a cooperative driver assistance system at an intersection by subjects of elderly drivers will be described in detail. The experiments with two experimental vehicles driven by the subjects were conducted along virtual, urban streets constructed on a test track. A traffic signal system was installed at an intersection of the streets.

5.1 The assistance system for the experiments

The assistance system for the experiments and evaluation by elderly drivers is the assistance on the right turning collision avoidance. The assistance system prevents the crash on the right turn or at a blind intersection, as shown in Figure 8. It provides the information to vehicles approaching the intersection, including the localization, the speed, and the behavior intention at the intersection (go straight or make a turn) with the inter-vehicle communications. It is also possible to provide information services, warnings, or braking control to the driver depending on the stage of danger.

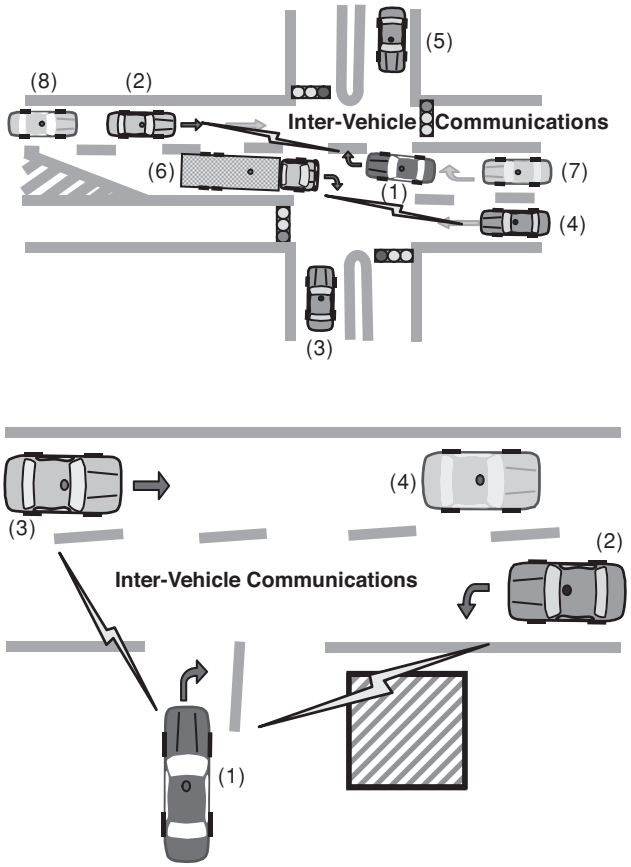


Fig. 8 Collision avoidance on right turning (top) and at a blind intersection (bottom)

When performing the inter-vehicle communications among vehicles, the communication link is essential for the assistance. For example, the links between vehicles (1) and (2), and vehicles (3) and (4) in the top of Figure 5, and that among vehicles (1), (2) and (3) in the bottom part of Figure 5 are essential. The control and the management of the communications are necessary, and the communication resource must be effectively utilized[9].

5.2 The experimental equipment

The vehicles have the functions of the inter-vehicle communications, the localization, and an HMI unit for instructions to a driver. Each experimental vehicle is equipped with a RTK-GPS receiver (Novatel RT-2), an onboard computer, the map database, the HMI (Man-Machine Interface) units besides an inter-vehicle communication unit. Figure 9 illustrates the configuration of the experimental vehicle.

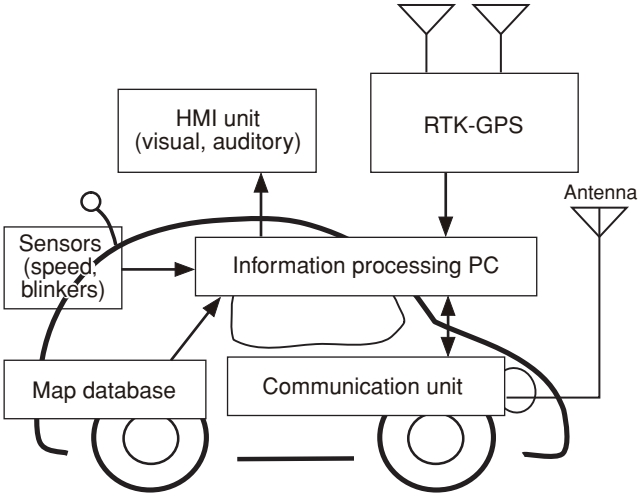


Fig. 9 The configuration of the vehicle for the experiments

The communication medium is 5.8 GHz DSRC (Dedicated Short Range Communication), and the protocol is based on the CSMA (Carrier Sense Multiple Access) protocol. The transmission power was 10 dBm, and the communication range was about hundreds of meters. The data transmission rate was 4 Mbps. The antenna was of omni-directional type.

The compensation data for RTK-GPS is transmitted by the radio modem from a base station installed on the test track control tower. The accuracy of the RTK-GPS was 2 cm under a vehicle quiescent state. The intersection position maintained as map database, and did positional recognition by 10Hz according to RTK-GPS information. The HMI unit or the on-board display is not for the practical use, but just for experiments.

5.3 The experiments

The experiments have been conducted with the new one-seat electric vehicle and a passenger along virtual streets on a test track with elderly driver subjects for the verification of the feasibility and effectiveness of the assistance.

A scenario of an experiment for the assistance to an elderly driver making a right turn is shown in Figure 10.

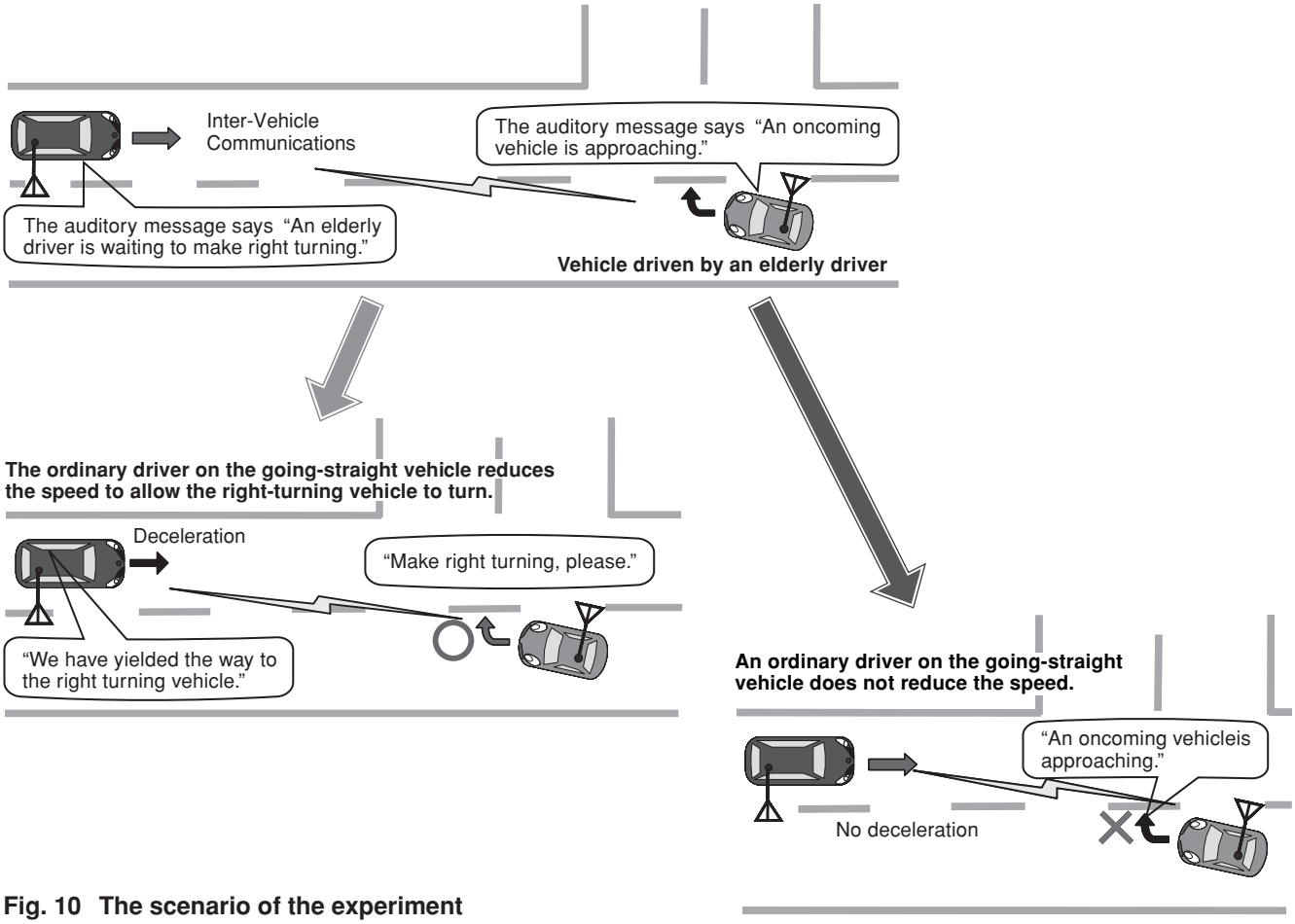
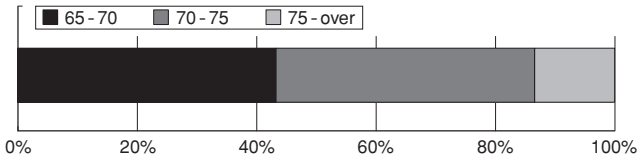
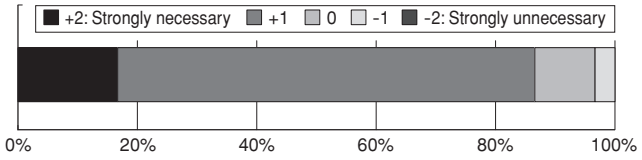


Fig. 10 The scenario of the experiment

Fig. 11 A scene of the experiments: the single seat vehicle is making a right turn and the oncoming passenger car is going straight



(a) Distribution of the age of the subjects



(b) Necessity of the assistance system

Fig. 12 The result of the evaluation of the system by 30 elderly driver subjects

At first, an elderly driver is going to make a right turn, and the information is transmitted to the oncoming vehicle. Then, an assistance system on the right turning vehicle receives information from the oncoming vehicle. The information is output in an auditory form: "A car is coming from the oncoming lane." On the other hand, in the vehicle which an ordinary driver is driving and is going straight, the information is output in an oral form: "An elderly driver is waiting to make a right turn on the oncoming lane." Then, the ordinary driver on the going-straight vehicle reduces the speed to allow the right-turning vehicle to make a right turn. Finally, on the going-straight vehicle, the driver hears "We yield the way to the right turning vehicle," and on the right-turning vehicle, the elderly driver hears "After you. Go ahead, please." On the other hand, if an ordinary driver on the oncoming vehicle does not reduce the speed, an assistance system on the right-turning vehicle warns the elderly driver not to make the right turn. A scene of the experiments with a right turning vehicle and a going-straight vehicle at the virtual streets is shown in Figure 11.

5.4 The evaluation of the assistance

The experiment was conducted with 30 elderly driver subjects. After the experiments, inquiries on the system were conducted with the subjects for the evaluation of the system. The concept of the cooperative driver assistance system was well recognized by almost all of them. Figure 12 shows the answer of the necessity of the assistance in the intersection proposed here. It shows that over 80% of the elderly drivers positively answered.

Some comments on the assistance from the subjects are as follows:

- Since it is difficult to estimate the speed of an oncoming vehicle, such an assistance system will be helpful for elderly drivers.
- Although the system may neglect the right of way and may make the traffic rules ambiguous, it is kind and helpful to provide the priority to elderly drivers.

5.5 Discussion

Although the fundamental experiment showed the effectiveness of the system, the following issues still remain, which must examined in the future.

1) Countermeasures to the mixture of vehicles with communication function and vehicles without communication function;
2) Identification of the receiver;
3) The accuracy and reliability of the localization;
4) Distrust and overconfidence in the system, and
5) The method and timing of the presentation of the assistance information;
6) It will be institutionally or legally difficult or impossible to introduce such an assistance system into busy, urban streets. The system will be suitable for elderly people communities or rural areas where the population is sparse and the number of elderly people is high.

6. CONCLUSIONS

A new concept of a driver assistance system consisting of two vehicles, i.e. a host vehicle (an assisting vehicle) and a guest vehicle (an assisted vehicle) has been proposed, and fundamental experiments with subjects of elderly drivers have been conducted to show the feasibility of the assistance system. The assistance system is for a single seat electric vehicle designed especially for elderly drivers.

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